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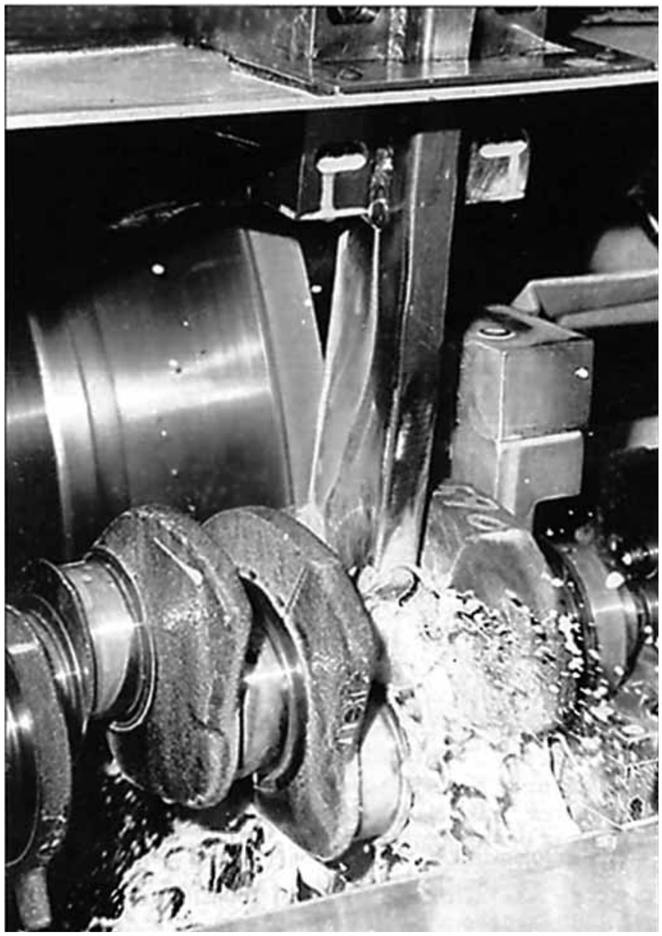
Don't let initial cost and perceived risk scare you

CBN GRINDING
A TEMPTING TECHNOLOGY



Landis CBN machines, shown doing pin journal grinding, are gaining acceptance in the US automotive industry.

For years, CBN grinding was on the fringes of machining technology. Manufacturing engineers used it only when they had to, usually because a metal was too difficult to cut or finish any other way. The picture is changing today with about 25% of all industrial grinding in Japan done with CBN, 15% in Europe, and 10% in the US. Although CBN use in the US is statistically low, interest is quite high. Predictions are that its use will expand dramatically for three reasons: conversion from other abrasives, chiefly aluminum oxide; introduction of CBN compatible grinders; and new applications as harder, more complex work materials are introduced.

According to data from GE Superabrasives (Worthington OH), global sales of CBN wheels was $145 million in 1988, reaching $300 million last year. The company estimates use can grow another 4.5 times to reach $1.6 billion.

In the US, CBN wheel sales for 1992 were an estimated $63 million, only a 13% penetration of the potential $480 million market. Currently, the automotive industry is the largest user of CBN wheels with 30% of the market, says GE. Tool production (both production and resharpening) is the second largest market with about 20% of sales. Bearing manufacturing is a growing application now representing 12% of total use. Aerospace and gear manufacturing follow with 9% and 8%, respectively. As to grinding techniques, CBN has made its greatest inroads with ID grinding because wheels are smaller and, therefore, less costly.

Why It's Better

CBN has many advantages over conventional abrasives. It is twice as hard as aluminum oxide, so a CBN wheel lasts longer, often 100 times or more.

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Robert B. Aronson
Senior Editor

This material also offers the potential for improved production through better finish, greater part consistency, and tighter tolerances. CBN can offer a significant time saving in high speed production because wheel dressing is less frequent. CBN grinding is not limited to traditional finishing operations. Its potential for fast material removal means it can sometimes eliminate machining steps. In some cases, grinding can do in one setup what would otherwise require milling, grinding, heat treating, and polishing. Grinding drill bits from bar stock is one such application.

'Today, high-speed grinding (16,000-40,000 sfm, 80-200 m/s) accounts for about 3% of all CBN grinding. Some experimental systems claim 100,000 rpm. But "high speed" is not well defined. According to Mike Brooks, a Borozon CBN engineer with GE Superabrasives, most work with CBN is done at speeds between 8000 and 12,000 sfm (40 and 60 m/s), although cam grinding, a major CBN application, is done at 16,000 sfm (80 mps). These speeds are also typical of most aluminum oxide grinding. "But," says Brooks, "because CBN grinding is cooler, there is less tendency to burn. The bottom line is higher speeds mean lower wheel cost because of longer life and improved quality. "

Society of Manufacturing Engineers

Another unique feature of CBN, residual compressive stress, leads to higher quality parts. Evidence indicates metal surfaces contract during CBN grinding, eliminating the microscopic surface cracks that typically exist in steel. This makes the metal stronger in many applications. On the other hand, when grinding burns metal, the heat generated expands the surface and opens the microcracks and encourages early failure.

Some CBN users say residual compressive stress allows reducing component size because the individual elements can take greater loads. One example is an automotive transmission where smaller, but stronger, CBN-ground gears allowed a size reduction.

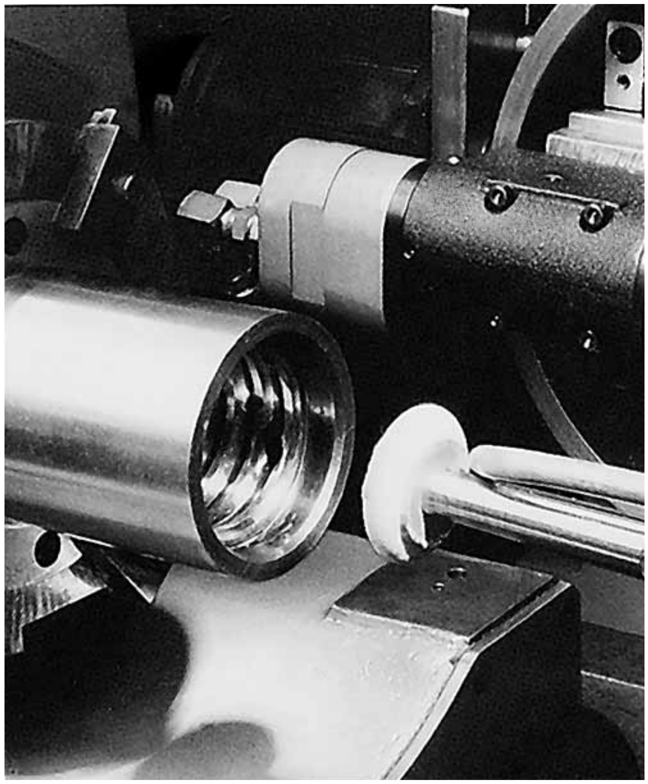
Cost Problems

The major negative is initial cost. First, there is the cost of the wheel. A 10" (254 mm) aluminum oxide wheel might cost $150; whereas a comparable CBN wheel might sell for $1500. This "sticker shock" keeps many first-time buyers away. CBN wheel prices have dropped 50% over the last 10 years, according to data from GE Superabrasives, and continue to fall as sales volume increases. This trend encourages users to look at CBN as a viable production technology, but total cost, performance, and part quality are still the deciding factors.

Another major cost consideration is the grinding machine. It isn't always practical to just bolt a high cost CBN wheel onto a conventional grinder. Absence of a truing and dressing system or lack of machine rigidity won't give the user the full benefits of using CBN. Top of the line machines sell for around $100,000 to $500,000. If those costs are too great, a user might upgrade or rebuild an older machine to use CBN wheels.

A difficult-to-predict cost is loss from operator error. One crash of a large CBN wheel can instantly wipe out any economic advantages, so operator training is essential. CBN wheel makers say that working with CBN is not difficult, it's just different. Operators must understand the CBN wheel takes careful handling and it can't be treated like a $10 wheel.

The first step in exploring CBN is to know your costs and production needs intimately. In trying to sell CBN grinding wheels and machines, suppliers complain that manufacturing engineers usually don't have a clear understanding of their own grinding costs. They usually have data available on the cost of the work material and expendable supplies such as wheel and coolant costs, but little beyond that. You need a more complete analysis, both up and downstream. This includes an in-depth analysis of the less obvious items that increase operating costs such as scrap, coolant maintenance, waste disposal (both swarf and coolant), production downtime due to wheel changes and other maintenance, diamond truer cost, and wheel breakage. Then it's important to get numbers for the benefits of increased production cycle, lower scrap rates, and higher part quality. With those figures in hand, CBN's benefits may become more obvious.



Remanufactured machines, such as this thread grinding machine from Drake Manufacturing, is one way around the high cost of new CBN grinders

What Machine?

Many of the grinders using CBN in the US are imported. The Japanese have broad experience and have done well in grinding production parts. Toyoda (Wixom, MI) has specialized in automotive applications such as camshaft grinding and made major sales to Ford.

Conventional cylindrical grinders operate at 6500-12,000 sfm (32-60 m/s). The most recently introduced Toyoda machine, the GZ32P operates at 40,000 sfm (200 m/s) using a thin vitrified CBN wheel for slot grinding. European based grinder manufacturers, such as Junker (West Springfield, MA), Guehring (Sussex, WI), and Maegerle (Schaumburg, IL) are known for specialized applications such as high-speed cylindrical, surface, and creep-feed grinding.

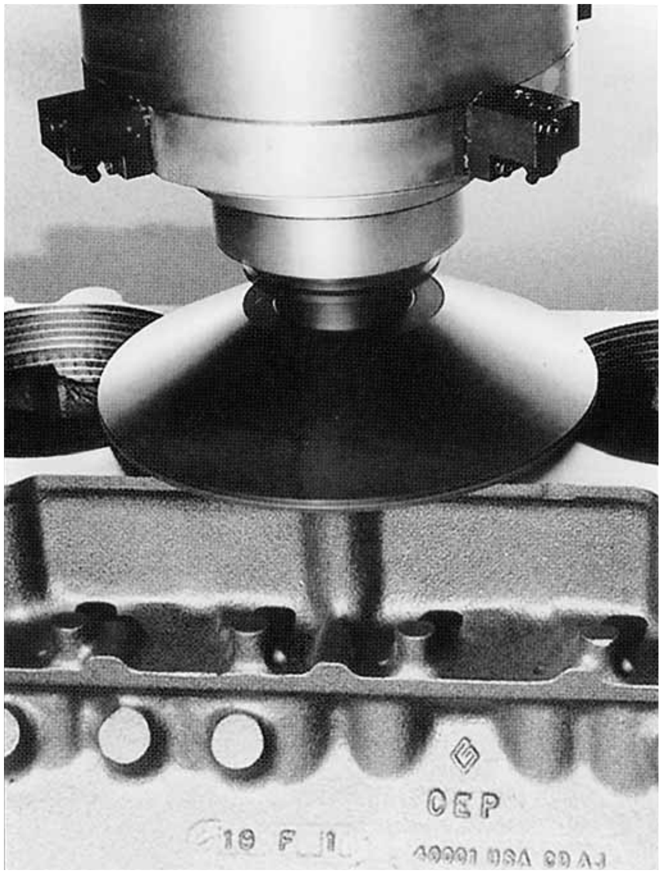
In the US, some grinder manufacturers are just turning their attention to grinders designed for CBN. According to Pat Harrington, vice president, engineering, Bryant Grinder Corp. (Springfield, VT), his company has designed machines around the CBN process for six years, but the company only recently designed one from the ground up for CBN, their UL2. Bryant specializes in ID grinding with most wheels in the 1. 5" (38-mm) diam. range. "We took on this design because the effectiveness of CBN was becoming obvious," he says. Bryant is also working with the University of Connecticut to develop a super high-speed OD CBN grinder.

Huffman (Clover, SC), another old-timer in the US grinding industry, recently offered a six-axis grinder with CBN capability. The company has had significant success in tool manufacture and maintenance with CBN.

One of the newer entries with a machine specifically designed for CBN is Edgetek, (Middlefield, CT), a company that offers a plated-wheel system selling for about $225,000. They refer to the type of grinding their machine does as high-efficiency deep grinding (HEDG), a form of high-speed creep-feed grinding. HEDG is said to have the advantages of material removal rates as high as those of conventional machining and ability to cut hardened parts with no damage due to heat.

Campbell Grinding Co. (Muskegon MI), a company with an aerospace industry niche, makes rotary vertical grinders using all types of CBN wheels. The company's major market is in the jet-engine part manufacture, chiefly shafts and vanes. But it is expanding into other aerospace and automotive applications. Campbell recently introduced a model with a turret changer and automatic part inspection. This design allows using both CBN and conventional abrasive wheels on the same part, but needs a wide speed range to accommodate both types of wheels.

Weldon Machine Tool, Inc. (York, PA), has offered CBN compatible grinding machines for more than five years. According to company president Jim Flinchbaugh, they have specialized in cylindrical grinding with an emphasis on punch applications. "In developing our CBN capability, we stress customer ready' machines. We want to make the customer's transition to CBN easy, so we pay close attention to those aspects of the process that are somewhat different, such as dressing cycle, wheel speed, and coolant application."



Feasibility study by LeBlond Makino combined a plated CBN wheel with conventional tools in the MC98 machining center. The wheel finish ground a diesel block and the "machining/ ginding" center performed all the functions of a 26-station transfer line.

Landis Grinding Machines (Waynesboro, Pa.) is successful in the automotive industry with significant sales of CBN grinders to both Ford and GM for engine component manufacturing. According to Bill Pflager, manager of R&D, the company is making a major push into CBN grinding. Their OD grinders were redesigned to have the capabilities CBN requires. "Right now, it is a break-even situation in some applications because of the high up-front wheel cost," says Pflager. "But we are confident that long-term results will show the merits of CBN."

Mattison Surface Grinders (Rockford, IL) has offered CBN, "Since someone first thought of the material," according to company president, Phil Mattison. "Moving to CBN didn't take any major redesign of our machines because we have always had a rigid design. We did have to add the precise dressing and positioning systems CBN requires, however."

The company now offers surface grinders with both plated and vitreous bonded wheels. The largest wheel, a 24" (600-mm) diam. vitrified bond unit, runs at nearly 22,000 sfm (110 m/s). "We have run wheels experimentally at 26,000 sfm (130 m/s)," says Mattison. The company also offers double-disc grinders for CBN operating at 6000-8000 sfm (30-40 m/s). Mattison says about half their output is currently sold overseas.

Late in 1993, GE Industrial Power and Systems Div. (Greenville, SC) made a major move toward CBN by bringing in five German-made Blohm (Richmond, VA) RT-HSGE grinding centers. The machines are dedicated CBN machines operating at 9000 sfm (45 m/s) and doing general surface grinding jobs on a number of gas turbine components. This is a case where high speed was unnecessary. Nelson Beaulieu, an engineer for Blohm Grinding Systems, says their company feels they can do most CBN grinding tasks adequately at speeds around 9000 sfm (45 m/s).

What's Required?

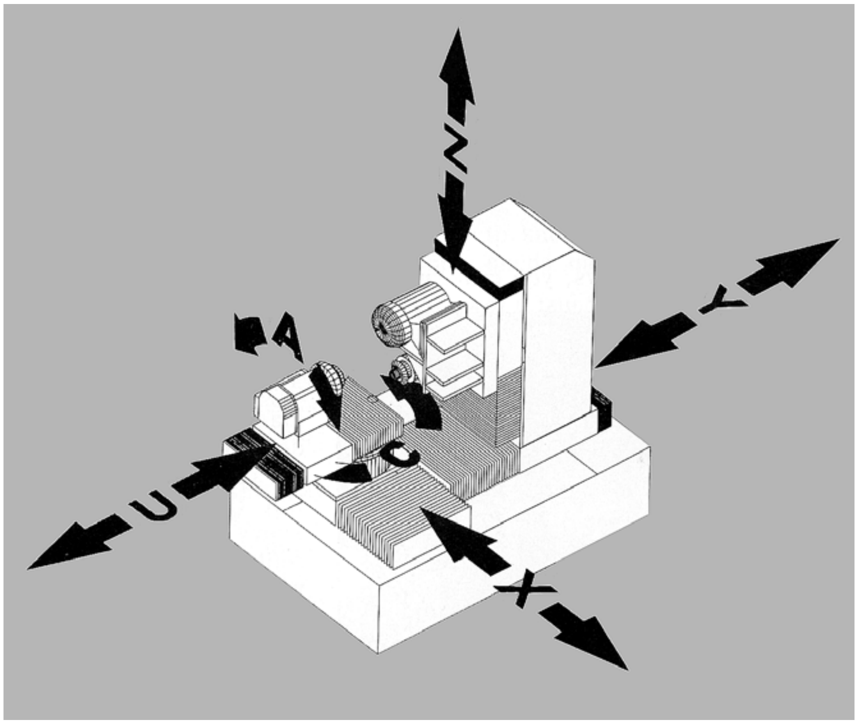
For a grinder to use CBN successfully, it must have the necessary stability, conditioning devices, positioning, gauging, spindle speed, and cooling system.

Stability. The machine must be strong and stiff to resist the dynamic loads and minimize vibration. Grinding machine builders frequently use an artificial granite from suppliers such as Anorad I Hauppauge, NJ), which, company spokesman say, has 45 times the vibration damping capability of steel. This material both increases machine mass and has low transmissibility. Both features reduce vibration resulting in a better surface finish, tighter tolerances, and longer tool life. The composite bases also reduce thermal distortion. According to Anorad, about 60% of domestic grinder manufactures use some form of composite in their designs.

Heat generated by operations and transmitted to the machine from the environment can distort a grinding machine significantly. Considering certain critical features minimizes this distortion such as spindle shaft size, fixtures, and distance between the grinding-wheel shaft and workpiece.

Conditioning. Special care or conditioning of a CBN wheel is essential. Although definitions vary, conditioning is usually considered the truing and dressing of the wheel. Truing refers to the wheel's roundness and balance; dressing is the condition of the abrasive on the wheel's surface.

Conditioning methods depend on the type of CBN wheel, bond system, and application requirements. Resin and metal-bonded wheels need separate truing and dressing operations because



Huffman six-axis design shows versatility of new grinding centers.

the bond material is not porous. Truing requires a silicon carbide wheel brake device or a powered rotary diamond disc. Dressing uses a stick of aluminum oxide. Both operations can be manual or automated.

The porous structure of vitreous bonded wheels responds well to rotary diamond conditioning so these wheels can be trued and dressed in one pass. The diamond wheel rotates at about 0.4 to 0.6 times the speed of the CBN wheel and essentially "machines" off some of the wheel's surface. In grinders designed for higher speed production, this operation is automatic and triggered by the wheel's condition. Electroplated wheels, or metal-brazed single-layer wheels function without conditioning. Some systems, however, use "touch dressing," which removes a small fraction of the grit to maintain the desired cutting ability and surface finish.

Because of CBN's hardness, dressing most wheels with a single point diamond, as is done with many other abrasives, is impractical. Diamond wear caused by the CBN is so great that it cannot maintain a consistent dress across the wheel's surface. New vitreous bonds now under development may make single-point truing possible in the future, however.

To dress properly, the operator must know where the wheel is so the dressing wheel can make the required depth of cut, particularly when dealing with micron measurements. One development that has made accurate dressing possible is an acoustic touch sensor. The instrument, used with the dressing system, tells the operator when the dressing wheel and CBN wheel are about to touch. This establishes a reference point from which to make the dressing pass.

Positioning. Positioning accuracy in the millionths of an inch is necessary to exploit the finish CBN can provide. A servomotor and ballscrew feed system provides the submicron accuracies.

Gauging. The success of CBN grinding depends heavily on precise gauging. The operator needs to know not only where the cutting tool (the wheel) is but how much the wheel is wearing. Three types of gauging cover these requirements. High-precision work requires all three.

• In-process gauging checks the part and indicates when a specific cut is completed.

• Post-processing gauging feeds back trends on part dimension shifts so the control system can adjust for changes in machinery or wheel wear.

• Wheel gauging, the acoustic signal mentioned earlier, locates the position of the wheel before dressing so it makes the dressing cut precisely.

Spindle. The higher wheel speeds and stiffness requirements are causing grinder builders to go to special electric drives and hydrostatic bearings. They are also developing adaptive control for the grinding process based on power or force monitoring.

Coolant. Controlling heat is essential both to maintain accuracy and to prevent wheel failure. CBN has a much higher heat transfer rate, about 40 times that of aluminum oxide, so the material itself

America First?

Stung by the need to go offshore for the latest grinding technology, Pratt & Whitney (Hartford, CT) joined forces with the National Center for Manufacturing Sciences (Ann Arbor, MI) to try a project called, "US Grinding Partnership 2000. " It's goal is to define and carry out a number of programs that will make the US a world leader in grinding technology by the year 2000. These efforts would link equipment suppliers and users. The NCMS has completed initial research on defining programs, and if approved, could have projects underway soon.

In another attempt to boost the quality of US grinding technology, the University of Connecticut (Storrs) has several programs at its Advanced Technology Center for Precision Manufacturing and Center for Grinding R&D. These projects are currently underway:

Precision spindle. It will have interchangeable bearings (aerostatic, rolling element, magnetic, and hydrostatic).

Slideway. It combines both stiffness and precision.

Infinite stiffness aerostatic bearing. It will work with piezoelectric restrictors to control stiffness and withstand an applied load of 250 N.

High-speed CBN grinding machine. It will operate at 50,000 sfm (250 m/s) and have a water-based lubrication. Bryant Grinder Corp. and Torrington Co. (Torrington, CT) are collaborating.

High-speed wheel. A flexible rim will filter out high-frequency vibration to reduce chatter.

helps inhibit heat build up. High-speed cutting can be relatively cool, but it requires high pressure coolant flow and specially designed nozzles or wheels to get the coolant into the work zone.

There is currently a lot of effort to find the most efficient coolant for CBN operations. Oil lubricates better and leads to longer wheel life. The down side is the environmental issue. Disposing of oils is difficult, particularly when they are contaminated. They also have some in-plant disadvantages. Blohm, for example, recommends staying with oil as a coolant. "Will what you save on wheel life pay for the clean up cost? You have to look at each job." says Blohm engineer Beaulieu. Water-based coolants are widely used, however, with somewhat decreased performance.

CBN product manager Joe Eramo of Abrasive Technology (Westerville, OH) says his company has developed, through a USAF contract, a system to enhance CBN wheel life in a watersoluble coolant. According to Eramo, "The system can be optimized for water to achieve wheel life that meets or exceeds current performance in oil. It involves CBN grit size, bond type, as well as coolant velocity, flow rate, and other critical variables."

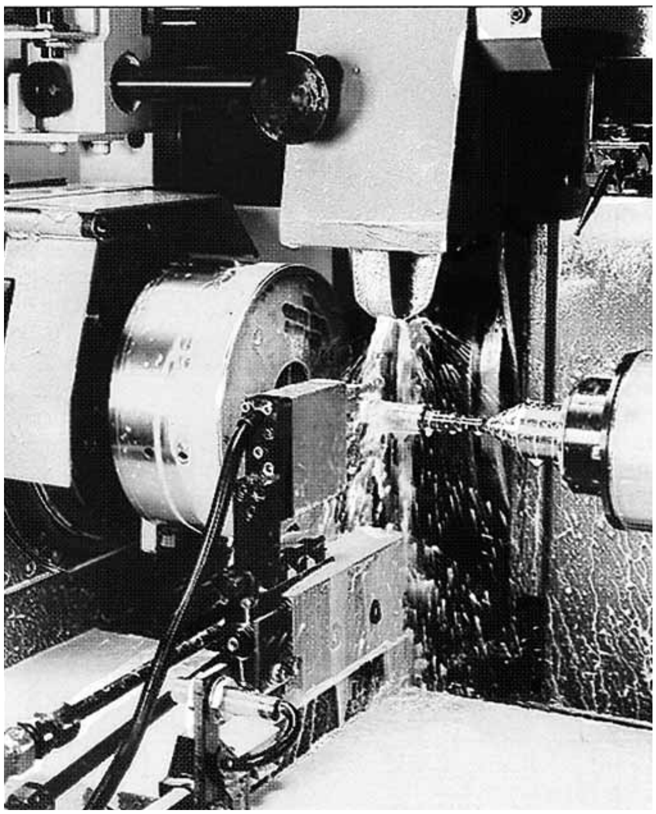
Whatever the fluid used, most experts recommend coolant temperature control to minimize heat buildup and thermal shock to the workpiece and wheel. Filtering is also essential because grinding generates micron size debris.

Control. Last but not least is control. To deliver the precision CBN grinding requires the controller needs software that works with all variables. For example, Bryant's Harrington says that an important consideration is dress programming: "The software should determine dress time based on a power analysis."

New Isn't Necessary

If the application allows, you can get into CBN grinding for just a few thousand dollars: the wheel plus some reworking of an existing grinder. The main thing is to increase rigidity which can be done by getting a more rigid spindle, improving the fixturing, and possibly adding truing and dressing systems.

Although a reworked machine providing the same benefits as a new CBN grinder is unlikely, you might get enough to meet your specific job requirements. The key is preparing an accurate analysis of what you want done and what a reworked machine can do. Industry experts, however, caution, "CBN novices should not try this on their own."



Toyoda's latest grinder, the GZ32 CNC/CBN, features a spindle bearing with a rotational accuracy of 0.1μm.

Used machines may also meet your needs. According to Mike Drake, president of Drake Manufacturing (Warren, OH), a company that remanufactures machine tools, "There are many old machines out there from the '40s on, so reworking those old units offers an alternative to a new half million dollar machine. Grinding is a fairly mature industry so profits are not great and not too many can afford new machines. For less than half the cost of a new machine we can put today's technology into an old unit by adding a diamond roll dressing, servos, ballscrews, and stiffer spindles. Many older machines were overdesigned, so rigidity is not a problem in a rework. But that doesn't mean every machine can be refitted. Some are only worth their scrap price.

"With our rework, we can dress to I micron and position to 0.1 micron," Drake continues. "But thermal problems can be a big headache. It's difficult to correct after a machine is built. You can't bring a bad machine back with gauging.

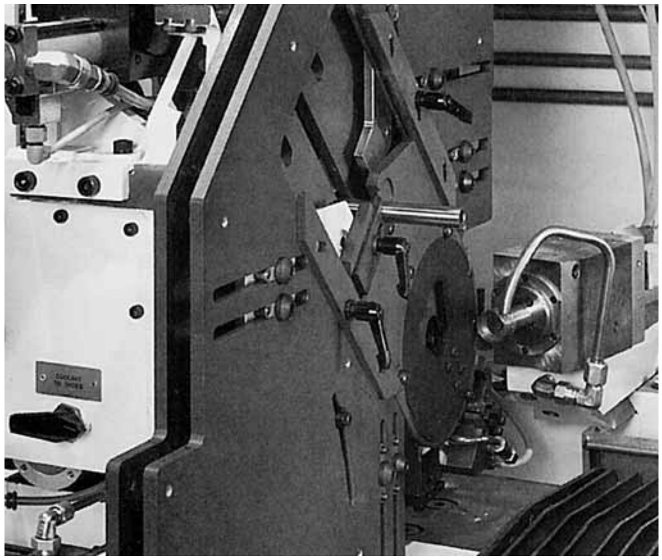
Wheel Types

There are two broad categories of CBN wheels: bonded and plated. With bonded wheels, the manufacturer blends abrasive of various grit with a resin, ceramic, or metal matrix bonding material. Resin is the most compliant and used for applications such as toolmaking. Metal is the stiffest and used for rough and form grinding. For example, the German manufacturer Junker uses a narrow steel-bonded wheel for lathe-like grinding applications. The vitreous bond is the most versatile and currently most frequently used for automated, high-productivity grinding.

The manufacturing process shapes the mixture of grit and bonding material around a core. Because CBN wears slowly and is costly, the amount of bonded CBN material is typically 3-5-mm thick. The core can be aluminum, steel, or, in the most recent developments, a composite. Composite core wheels, such as the experimental carbon fiber version offered by Noritake Co. (Cincinnati), can handle speeds up to 40,000 sfm (200 m/s). The wheel core or hub material is critical because of high centrifugal forces. Cores made of high strength, ductile materials such as steel and aluminum absorb these stresses.

To reduce costs and minimize the hazards if a wheel crashes, some large CBN wheels have solid cores and vitrified-bond CBN segments. This design allows for some thermal expansion and also limits the amount of CBN lost in a crash. A segmented wheel cuts better in some applications because it reduces burn and loading of chips and grit.

According to Dr. Mike Hitchner, Universal Superabrasives (Romulus, MI), "Conventional vitrified-core wheels have burst speeds of 24,000 sfm (120 m/s); metal-cored segmented vitrified wheels have burst speeds of 50,000-52,000 sfm (250260 m/s). And we are working on Kevlarbased cores, which may have burst speeds as high as 90,000 sfm (450 m/s). These high wheel speeds are not possible for all CBN operations. ID and double-disc grinding, for example, are still limited to the same speeds as conventional vitrified wheels. ID grinding can have some problems with quill whip and hydroplaning at speeds much above 10,000 sfm (50 m/s)."


Work area of a Bryant's new "Ultraline" UL2 grinder

The plated wheel has a steel core and one layer of CBN grit. The benefit of this design is the wheel can have any machinable contour. There are two types: conventional electroplated and metal single layer (MSL). The MSL configuration exposes about 60% of the grain to give more cutting action. In a conventional plated wheel, about 40% of the CBN crystal is exposed. MSL does not achieve as tight a tolerance in some instances, however.

Abrasive Technologies' Eramo makes a strong case for plated wheels over bonded wheels. Some advantages he lists are manufacturing to tight tolerances on complex shapes, eliminating dressing, increasing operating speeds, and ability to be replated and reused. LeBlond-Makino (Mason, OH) and GE Superabrasives Application Development Lab are working on plated wheels to use in LeBlond's machining centers. These grinding tools are included in the tool magazine and used as needed.

Maybe Not CBN

Some have compared a move to CBN to buying a Mercedes and suggest that maybe you don't need that kind of quality to get the job done. Maybe a Geo will do as well. The answer is in knowing which system works best for your product.

For example, both Norton (Worcester, MA) and 3M (Minneapolis) offer non-superabrasive grits that cover a multitude of applications. In wheel design, plastic bonded wheels are said to offer many of the advantages of CBN, but at one fifth the cost. Research Abrasives (Willoughby, OH) claims their plastic-bonded wheel with aluminum oxide grit has taken a number of jobs from CBN operations. The downside to plastic is it wears faster than CBN.

Meanwhile, 3M and others are moving ahead with a variety of belt abrasives. J.D. Phillips Corp. (Alpena, MI) is applying abrasive belt technology on a grinder that can do multiple pins for the automotive industry and GM is reportedly using belt grinders for some of their camshaft applications. Although Ford has a strong commitment to grinding, Jim DeVerena, manufacturing engineer, engine division, says, "There's no clear cut preference for CBN. We do a lot of pin and cam lobe grinding, but we analyze each new job and decide on a cost basis. Right now, it's between aluminum oxide and CBN wheels. If the price of CBN comes down, we might do more jobs with it." ■